REMARKS

Claims 24-25, 28-37, and 40-45 remain in this application.

Applicants thank the Examiner for the telephone Interview of April 6, 2010. This Amendment includes the substance of the Interview.

The claims as amended and pending describe a mobile fumigation system that requires the use of an <u>ISO general purpose shipping container</u> which is effective for allowing use of <u>toxic</u> fumigants. The pending claims include the following elements:

- Fumigation chamber
  - Gas tight ISO general purpose shipping container for use with <u>toxic</u> fumigants
- Fumigation apparatus for use with <u>toxic</u> fumigants
  - Operatively coupled to the fumigation chamber
  - Inlet device
  - Extraction device
  - Absorption device

<u>Rejections under 35 USC 103</u>

<u>Williamson does not teach the use of a fumigant, let alone a toxic fumigant</u>. In fact Williamson teaches that hot air should be used instead of fumigant. For example, we refer to column 3, line 8, lines 30-33 and line 58. Column 3 lines 30 -33 indicates:

> ". . . heating the commodity inside of a plurality of bins in one or more states with air having a temperature above the thermal death point temperature of the target . . ."

Thus, Williamson teaches away from using a toxic fumigant.

Otsuki clearly and expressly teaches away from the use of a toxic fumigant. In paragraphs 5 and 6, Otsuki makes it clear that toxicity is an issue, and that moving away from the use of a toxic fumigant is one of its primary objectives. Paragraph 7 of Otsuki states that a solution to this problem is to use carbon dioxide.

Wikipedia (www.en.wikipedia.org/wiki/fumigant) defines fumigation as follows:

> "Fumigation is a method of pest control that completely fills an area with gaseous particles - or fumigants - to **suffocate** **or** **poison** the pests within . . ." (emphasis added)

The authors of that entry have distinguished fumigation by suffocation from poisoning.

In the context of the cited documents and present application, carbon dioxide is not a poison. It is a component of the atmosphere and it is compatible with life. Substantial replacement of air with CO_2 - as done in Otsuki - suffocates life. Otsuki does not disclose a poisonous fumigant, that is a toxic fumigant, as understood in the present context.

Enclosed is a document entitled "Heat Treatment for the Disinfection of Empty Storage Bins." The article states in its introduction that:

> ". . . in recent years, there has been renewed effects to investigate non-chemical insect control measures due to concerns for the environment, worker safety, or consumer preference."

The enclosed document "International Standards for Photosanitary Measures" also anticipates the phase out of the toxic fumigant methyl bromide, as does the enclosed document "Heat Treatment: Capabilities and Limitations." The phase out is necessary because of the toxic properties and ozone layer depleting properties of methyl bromide.

As will be now appreciated, the person of ordinary sill would not be trying to invent a fumigation system using a toxic fumigant as it is common general knowledge that toxic poisons are generally undesirable. The applicants have through application of their ingenuity, against these teachings, invented a fumigation system that uses a toxic fumigant safely.

Given that neither Otsuki nor Williamson describe the use of a toxic fumigant, there is no reason for a person of ordinary skill in the art to look towards Smithyman. Similarly, there would be no reason for the person of ordinary skill in the art to look at Haraguchi in light of Otsuki.

Consequently, incorporation of the feature of an extraction device to remove a majority of the toxic fumigant, and an absorption device operatively coupled to the extraction device, the absorption device being designed to absorb the toxic fumigant removed from the fumigation chamber, is inventive over the cited references.

Allowance of the pending claims is respectfully requested. The Commissioner is hereby authorized to charge any additional fees which may be required with respect to this communication, or credit any overpayment, to Deposit Account No. 06-1135.

Respectfully submitted,

FITCH, EVEN, TABIN & FLANNERY

Dated: JUN 10 2010

James P. Krueger
Registration No. 35,234

120 South LaSalle Street, Suite 1600
Chicago, Illinois 60603-3406
Telephone (312) 577-7000
Facsimile (312) 577-7007
562915

HEAT TREATMENT: CAPABILITIES AND LIMITATIONS

James Sargent*[1], Mark Sheperdigian[2], and Jeff Weier[3]

Heat treatments are an established, if obscure, method of disinfesting certain empty structures and equipment. Since the anticipated phase-out of methyl bromide fumigants, interest in this non-chemical pest management technique has been growing. Many of the advantages, disadvantages, considerations, observations, costs and results of using heat to disinfest empty food processing and storage structures are situational in reality. Like fumigation with methyl bromide, successful heat treatments depend upon trained personnel, careful preparation, employee cooperation, good weather, etc.

Some possible advantages of a heat treatment include the following:

- Perceived to be less dangerous than fumigation
- Fewer regulations than associated with fumigation
- Can monitor and adjust treatment easier than fumigation
- More effective than fumigation of a "leaky" structure
- More effective against pathogenic microorganisms

Some possible disadvantages of a heat treatment include the following:

- Generally ineffective at penetrating commodities and debris
- Significantly more expensive than a methyl bromide fumigation
- Exposure period may be longer than for a methyl bromide fumigation
- Strong potential for damage to equipment and structure
- Less known about actual heat treatments than fumigations

In spite of all the recent effort put into heat treatments, methyl bromide is still the most cost effective and efficient means of equipment and building disinfestation. However, heat treatments may be a good pest management tool for some situations where fumigation is not recommended (e.g. "leaky" structures or treatment of a small area). Heat treatments may also complement periodic methyl bromide fumigations (e.g. heat rises, methyl bromide sinks). Combination treatments involving heat and methyl bromide synergistically together or heating the structure and fumigating removed commodity and cleanings may allow for reduced use of methyl bromide.

Heat treatments require more sophisticated planning and much more air moving equipment than fumigation. Uneven heating increases the risk of damage and also exacerbating pest problems (short term and long term). Engineers who supervise heat treatments and who do not know pest biology and the hidden locations of pests risk failure. The goal of a heat treatment is not just to raise the temperature inside a structure to a certain level for a certain number of hours. The goal of the heat treatment is to kill all the pest species in whatever life stage they occur and wherever they may be found.

[1]Copesan Services, Inc., 3490 N. 127th Street, Brookfield, WI 53005
[2]Rose Exterminator Co., 1130 Livernois, Troy, MI 48099
[3]Sprague Pest Solutions, 2139 South Fawcett, Tacoma, WA 98402

During one commercial fumigation of a flour facility in 1999, small test vials were placed in 12 high locations, 12 low (floor) locations, and 12 mid-level locations in a large processing/packaging area. Each vial contained a tiny amount of flour with five adult confused flour beetles (Tribolium confusum) or five late instar larvae or approximately five eggs. All test specimens died during the 24 hour heat treatment where the maximum temperatures in the 36 locations ranged from 117° to 152° F. However, some resident insects in low spots (e.g. drains), in building corners, under objects on the concrete slab ground floor and inside small piles of flour inside milling or filling equipment or on the floor survived the treatment. It is interesting to note how adept the pests were at finding and exploiting insulated microenvironments within the treatment area.

To better determine heat sensitivity of stored product insect eggs, an abundance of two day old eggs with 8 grams of flour were placed in a 2 dram plastic vial. Ten mixed adults (parents of the eggs) were contained in a 2 dram plastic vial with approximately one gram of flour. Five common pest species were tested, including confused flour beetle, red flour beetle (T. castaneum), warehouse beetle (Trogoderma variable), saw-toothed grain beetle (Oryzaephillus surinamensis), and Indian meal moth (Plodia interpunctella). A set of ten vials were removed at two hour intervals starting at Hour 8 of the heat treatment. Saw-toothed grain beetle adults were more heat tolerant than the other four species with some surviving through Hour 12. Eggs of all species were more tolerant of heat than the adults however the immobile stage may have been better insulated by the extra flour. Warehouse beetle eggs were most tolerant of the treatment and survived past Hour 12.

One set of vials were placed in a space underneath the top layer of bags of flour on a loaded pallet along with a temperature monitor. The maximum temperature recorded at the vials was 88° F. while the maximum temperature near the loaded pallet was 148° F. All of the insects survived and the eggs seemed to have been stimulated by the heat treatment. More larvae and a more rapid rate of growth were noted 30 days after the heat treatment when compared to the untreated eggs held under the same conditions.

Certainly considerably more field data and experience is necessary before sweeping generalizations can be made on disinfesting an assortment of structures with heat. Questions are more common than answers. Why are there large differences in mortality of insects from the same genetic pool? How important is acclimation (e.g. killing insects in a 120° F. flour mill in the summer compared to a cooler season or cooler region)? What is the optimum pattern of temperature increase to maximize mortality of various pests in the least amount of time while minimizing damage? What is the best (easiest to observe, most difficult to kill) pest to use for monitoring the progress of a heat treatment?

Finally, heat treatments are touted as being nontoxic however exposure to heat can be unpleasant. The risk of heat related maladies are quite real and increases in direct proportion to the time spent in the heated environment. A common problem is a moderately uncomfortable skin irritation or rash for extended periods after the heat treatment. Also, depending on the amount of talking and manner of breathing, irritation of the upper respiratory tract can result from involvement in a heat treatment. It is helpful to be familiar with heat-related illnesses and steps should be taken to minimize heat exposure to humans, particularly to some extremely heat sensitive individuals.

Available online at www.sciencedirect.com
ScienceDirect
ELSEVIER
Journal of Stored Products Research 43 (2007) 221–228
Journal of STORED PRODUCTS RESEARCH
www.elsevier.com/locate/jspr

Heat treatment for disinfestation of empty grain storage bins ☆

Dennis R. Tilley, Mark E. Casada*, Frank H. Arthur

USDA-ARS, 1515 College Avenue, Manhattan, KS 66502, USA

Accepted 5 April 2006

Abstract

An alternative to fumigants and insecticides for controlling stored-product insects in empty grain storage bins prior to filling is heat treatment, in which the temperature is quickly raised to a minimum of 50 °C and held there for 2–4 h. Effectiveness of heat treatment on empty grain storage bins was evaluated for five commercial propane and electric heat-treatment systems by measuring air temperature and associated mortality of *Tribolium castaneum* (Herbst), the red flour beetle, *Sitophilus oryzae* (L.), the rice weevil, and *Rhyzopertha dominica* (F.), the lesser grain borer, exposed for different time intervals. Eleven locations, six above and five below the drying floor, were monitored for air temperature and associated mortality of the three insect species, using arenas initially stocked with live adult insects. Data were analyzed separately for each heating system, with floor location and time interval as main effects for insect mortality. A high-output propane heater (29 kW) produced 100% mortality in 2 h for the three insect species at all test locations. An electric duct-heater system (18 kW) also produced 100% mortality at all test locations after 40 h when aided by a complicated interior heat-distribution system. The other three systems produced less than 100% mortality.
Published by Elsevier Ltd.

Keywords: *Tribolium castaneum*; *Sitophilus oryzae* (L.); *Rhyzopertha dominica* (F.); Heat treatment

1. Introduction

On-farm grain storage bins are commonly inspected for insects prior to filling. Grain storage bins with perforated drying floors create an ideal harborage for insects (Raney, 1974) because the area below the drying floor is not normally accessible for cleaning unless the perforated floor is removed. Applying a registered insecticide to the walls and floors of empty bins supplements, but does not replace, sanitation and cleaning. Insecticide residues control insects that may have remained in hard-to-clean cracks and crevices or beneath the perforated floor, but maximum control of insects in the subfloor plenum requires fumigation or removal of the perforated floor and thorough cleanup. In recent years, there have been renewed efforts to investigate non-chemical insect control measures due to concerns for the environment, worker safety, or consumer preference. In addition, there is always the danger of insect resistance to chemicals in the target insect populations (Subramanyam and Hagstrum, 1995).

The challenge of controlling insect pests with a minimum of chemical insecticides has led to the development of integrated pest-management (IPM) strategies (Hagstrum et al., 1999). There are many definitions of IPM, but most have two important elements: monitoring-based decision making and multiple control strategies (Hagstrum et al., 1999). One of the central tenets of IPM is reduction in the use of chemical insecticides and use of more ecologically based control methods when possible (Campbell et al., 2004). A technique that has been used successfully for many years against stored-product pests is use of extreme temperatures (Fields, 1992). Use of elevated temperatures or heat treatments has long been recognized as an effective strategy for managing stored-product insects associated with food-processing facilities (Dean, 1911). In heat treatments of facilities, either gas, electric, or steam heaters are used to slowly heat the ambient air, with a long heat treatment period (24–36 h) necessary for the heat to

☆Mention of trade names or commercial products in this publication is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the US Department of Agriculture.

*Corresponding author. Tel.: +1 785 776 2758; fax: +1 785 537 5550.
E-mail address: casada@ksu.edu (M.E. Casada).

0022-474X/$ - see front matter Published by Elsevier Ltd.
doi:10.1016/j.jspr.2006.04.005

penetrate wall voids and equipment (Mahroof et al., 2003a).

Target temperature for effective disinfestation of a facility during a heat treatment should be at least 50 °C (Imholte and Imholte-Tauscher, 1999; Wright et al., 2002; Roesli et al., 2003). Most stored-product beetles are killed within hours after being exposed to temperatures of 50 °C or more (Fields, 1992). However, during actual heat treatments, temperature profiles in the facility vary and the time insects are exposed to the lethal temperatures can differ depending on their location in the facility (Mahroof et al., 2003a).

Prior research had indicated that a minimum temperature of 50 °C in the subfloor plenum of a grain bin should eliminate insect infestations. However, this area below the drying floor is a maze of steel framing that hinders uniform heat distribution. The objective of this research was to evaluate different sources of heat and heater configurations for controlling stored-product insects in steel grain bins prior to filling.

2. Materials and methods

2.1. Grain bins

Two-grain bins were used to conduct heat treatments and a third bin used as a control. Test locations in each bin were monitored for temperature and insect mortality. Insect mortality was determined using arena cages containing live insects. Five heating systems were tested independently, with three different lengths of tests selected to be suitable for each system as described in Table 1.

The steel grain bins located at USDA, Grain Marketing and Production Research Center (GMPRC), Manhattan, KS, were each 6.7 m in diameter with a height of 4.1 m from the drying floor to the eave of the bin. Two of the experimental steel grain bins, bins 1 and 2, were located outside and the other, bin 3, was inside the GMPRC pilot plant. For tests of the outside heat-treated bin, bin 1, an adjacent outside bin, bin 2, was used as a control. The perforated floors of bins 1 and 3 were covered with tarps during the heat treatments to retain more heat below the drying floor, which was the slowest heating part of the bin. Bin 2 was not altered but was monitored at identical locations for temperature and insect mortality during heat treatments in bin 1. For tests in bin 3, there was no adjacent bin to use for a control, so arenas were placed around the outside of the bin as controls.

2.2. Insects and arenas

Tribolium castaneum (Herbst), the red flour beetle, was reared on 100% whole-wheat flour at 28 °C and 65% r.h. *Sitophilus oryzae* (L.), the rice weevil and *Rhyzopertha dominica* (F.), the lesser grain borer, were reared on 100% whole-wheat kernels at 28 °C and 65% r.h., respectively. Arenas for insect mortality studies were 0.5-L, clear polypropylene containers with recessed lids, each containing 8–10 g of cracked hard red winter wheat, a HOBO® data-logging unit (Onset Computer Corporation, Bourne, MA), and 15 insects—five each from the three different species. Unsexed, 3–5-week-old adults of the *T. castaneum, S. oryzae*, and *R. dominica* were added to the arenas. Each arena was modified with a 1.27-cm diameter breathing hole covered with 20-mill nylon wire mesh-screen. Three sets of insect arenas were positioned in each sampling location, described in Fig. 1 and Table 1, of each heating system. An insect arena was removed from each bin location at each of

Table 1
Steel grain bin and heat-treatment layout of each heating system

Heating system	Time intervals (h)	Energy use (kW h)	Test bin	Floor location	Treated bin arena locations	Control bin arena locations
Electric system 1 (18 kW)	12, 27, 40	216, 486, 720	3	Above	6[a]	6[b]
				Below	5[c]	
Electric system 2 (18 kW)	12, 27, 40	216, 486, 720	3	Above	6[a]	6[b]
				Below	5[c]	
Electric system 3 (15 kW)	12, 27, 40	180, 405, 600	1, 2	Above	6[a]	6[a]
				Below	5[c]	5[c]
Propane system 1 (29 kW)	2, 3, 4	58, 87, 117	1, 2	Above	6[a]	6[a]
				Below	5[c]	5[c]
Propane system 2 (19 kW)	4, 6, 8	76, 114, 152	1, 2	Above	6[a]	6[a]
				Below	5[c]	5[c]

Each heating system held three sets of insect arenas in each bin location. An insect arena was removed from each bin location at each of three specified time intervals. Three replications of each test were conducted with temperature and mortality results recorded.

[a]Arena sampling locations located above the bin drying floor of bins 1, 2, and 3 at the north, south, east, west, center, and top.

[b]Arena sampling locations of bin 3 located on the exterior perimeter at the north, south, east, and west.

[c]Arena sampling locations located below the bin drying floor of bins 1 and 2 at the north, south, east, west and center.

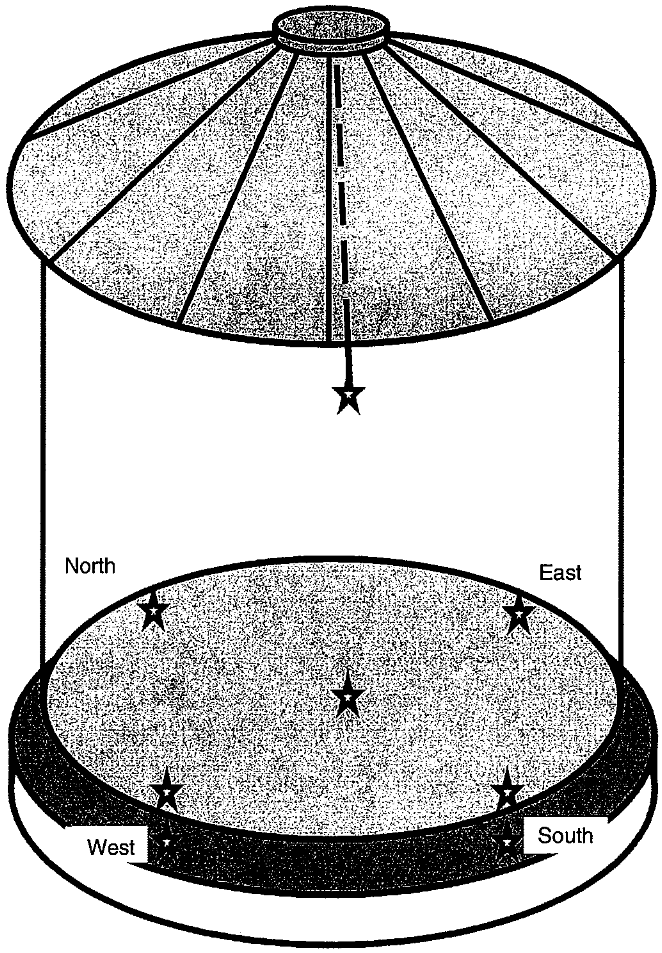


Fig. 1. Insect arena test locations in the grain bin fitted with a slotted drying floor. Eleven test locations (*) were determined, five above and five below the drying floor at the north, south, east, west, and center locations, and one suspended from the ceiling. Each test location contained three individual arenas. One arena was removed from each location at predetermined time intervals during a heat treatment and insect mortality determined.

three specified intervals. These time intervals were selected to be in the range where each system was expected to achieve temperatures of 50 °C. The times were also selected to be practical for field operations as far as possible, given the heat input of each system. Upon removal of each arena, mortality was assessed by examining each individual insect for movement. Beetles were probed repeatedly, and those that were on their backs and immobile were classified as dead. These insects displayed the typical form of dead insects; bodies were dried, legs were tucked under the abdomen, and there was no response from probing. A recovery period was not considered necessary because they were not "knocked-down," as is normally the case when stored-product beetles are exposed to residual insecticides. Methods for assessment of mortality were consistent with other studies in which stored-product beetles were exposed to lethal temperatures. Three replications of each test were conducted. After mortality was assessed and recorded, the insects were discarded.

2.3. Heating system selection

The five heating systems tested on the outdoor and inside grain bins were selected as follows:

- Electric system 1. An electric duct heater with an interior fan distributor. This system was selected to emulate a typical, low-temperature grain-drying system and was the largest heater, 18 kW, that could be found for the existing electrical system (480 V, 30 A).
- Electric system 2. Same as electric system 1 but with recirculation of the warm exhaust air and no interior distributor.
- Electric system 3. Portable electric heater (rated at 15 kW by the manufacturer: Chromalox, Inc., Pittsburgh, PA) with recirculation. Selected because it was the largest heater that could be found for the available electrical system (208 V, 50A).
- Propane system 1. Portable propane heater at high output, 29 kW. Selected because it was a standard-size, low-cost, and readily available forced-air heater (three-stage heater with manufacturer ratings of 19.0, 24.9, and 29.3 kW, Master Distributors, Grand Rapids, MI).
- Propane system 2. Portable propane heater at low output, 19 kW, was the low output setting of propane system 1 and selected to be comparable to the power of electric system 1.

A daytime high temperature of 26.7 °C or higher was required before starting a test so there would be consistent starting temperatures for all tests. The temperature of 26.7 °C was selected because it was consistent with the summer normal daytime high temperatures and the heater power ratings that had been selected to work at those temperatures.

2.4. Electric systems

Electric system 1 simulated a bin designed for low-temperature grain drying. These types of bins could likely be heat treated as part of an IPM approach, with only minor modifications. The heater was installed in the air-supply duct between the bin wall and fan of bin 3. The fan inlet was restricted to reduce airflow from this large drying fan (18.6 kW motor) to 0.33 m^3/s. The low airflow was required to limit heat loss in the exhaust air. An interior fan-distribution system was used to distribute heated air beneath the drying floor inside the bin. A 0.75 kW, tube-axial fan was placed inside the bin in the center on the drying floor with 12, 8.9-cm diameter metal flex tubes attached to an inlet manifold. Each of the individual metal flex tubes extended to the perimeter of the bin and below the drying floor, which was covered with a tarp to force the hottest air to flow beneath the drying floor. The flex tubes were spread around the perimeter with a greater concentration around the furthest point from where the heat entered the bin. Six of the tubes were placed in the

quadrant opposite that from where the heat entered the bin (north quadrant), three each in the east and west quadrants, and none in the south (heat entrance) quadrant.

For electric system 2, the interior fan/manifold distribution system was removed. A 25.4-cm diameter insulated flexible tube connected the heater's air inlet to a port entrance on the bin roof. Airflow was doubled to 0.66 m^3/s to provide better air distribution than the low airflow provided; the higher rate did not cause more heat loss in exhaust air because air was being recirculated with this system rather than being exhausted from the bin. Weights were placed on the tarp to keep it in place with this airflow. Fiberglass-insulated hard duct board was formed around the metal flange on the exterior, between the heater and bin wall, to limit heat loss.

For electric system 3, a similar method of recirculating heated air back to the heater inlet was used, as with electric system 2, using a 25.4-cm diameter insulated flexible tube. Airflow of 0.66 m^3/s was obtained by adding a 0.75 kW aeration fan to the inlet to supplement the portable electric heater fan. A weighted tarp was used again to force heated air below the drying floor.

2.5. Propane systems

The propane heater was modified with a pressure switch wired to turn off the propane supply and disable the unit if the fan blower malfunctioned. A thermal switch limited ambient air temperature entering the heater to 29.5 °C because, according to the manufacturer, temperatures above that could disable the unit. A small forced-air fan was attached to the heater's electrical component box to help cool the unit. An additional safety feature included in the system was a propane leak detector with shut-off valve. Two 45.4-kg propane tanks were connected to the unit. Propane tests were conducted on bin 1. The heater was connected to the plenum, with an insulated transition, through the existing drying-fan opening.

Data were analyzed separately for each heating system, with floor location and time interval as main effects for insect mortality. The General Linear Models procedure (SAS Institute, 2002) was used for data analysis and to separate means when main effects were significant. Mortality was compared when appropriate using the *t*-test procedure of SAS.

3. Results and discussion

All control arenas had 0% mortality for each heating system for *T. castaneum*, and *R. dominica*. Controls had 0% mortality for *S. oryzae*, except for propane systems 1 and 2, which had a maximum mortality of two rice weevils per arena for each of the three replications. Propane system 1 (29 kW) was the most effective resulting in 100% mortality, with standard error of 0.0, for all insects within 2 h and raising all test locations in the treated bin above 50 °C. However, this was accomplished at the expense of localized overheating, particularly below the drying floor near the heat source. Temperatures were significantly different above and below the floor and between time intervals for this heating system (Table 2). Temperatures in the bin below the drying floor reached a maximum of 112 °C. Bin temperatures crossed the 50 °C threshold, (Fig. 2A) in less than 1 h. Lower temperatures in

Table 2
Electric and propane heating systems mean temperature (mean ± SE) above 40 °C for each floor location and time interval

Heating system	Floor location	Time (h)		
		12	27	40
1. Electric system 1 (18 kW)	Above	52.2±1.5 aA	52.4±1.6 aA	52.9±1.4 aA
	Below	54.4±1.2 aA	55.4±1.2 aA	56.3±1.1 aA
2. Electric system 2 (18 kW)	Above	55.6±1.2 aA	57.0±0.6 aA	57.5±0.7 aA
	Below	52.4±1.4 aA	54.0±1.1 aA	54.9±1.2 aA
3. Electric system 3 (15 kW)	Above	45.1±1.2 aA	48.2±1.1 aA	47.3±0.8 aA
	Below	48.8±0.3 bB	51.7±0.5 bA	51.7±0.3 bA
		Time (h)		
		2	3	4
4. Propane system 1 (29 kW)	Above	59.4±0.9 aA	61.9±0.9 aA	60.1±3.1 aA
	Below	67.3±0.5 bA	70.1±0.4 bB	71.9±0.3 bC
		Time (h)		
		4	6	8
5. Propane system 2 (19 kW)	Above	49.5±3.1 aA	51.3±2.9 aA	52.2±2.6 aA
	Below	53.1±0.7 aA	55.0±0.9 aA	56.4±1.0 aA

For each of the five heating systems, means for above and below the floor followed by the same lower-case letter are not significantly different; means between time intervals followed by the same upper-case letter are not significantly different ($P \geqslant 0.05$, Waller–Duncan *k*-ratio *t*-test).

the other test applications resulted in less than 100% mortality, except in electric system 1 (18 kW) at the 40-h test (Tables 3 and 4).

All test applications, except electric system 3, produced localized overheating causing the mean temperature profiles to be above 50 °C for most of the tests. Even though most means were above 50 °C, many tests had localized cool spots that did not reach 50 °C. Test locations farthest from the heat source under the floor increased in temperature slowly. Because the heat entered on one side under the floor, the greatest overheating occurred under the floor. Because the under-floor supports impeded airflow, the greatest under heating also occurred under the floor. Above the floor, there was less temperature variation, less overheating, and rarely any under heating. The net result below the floor produced higher mean temperatures than above the floor, but also produced lower overall mortality in many cases because of the under heated locations below the floor. The mortality results below 100% (Tables 3 and 4) corresponded to cases where some under heated locations did not reach the 50 °C target.

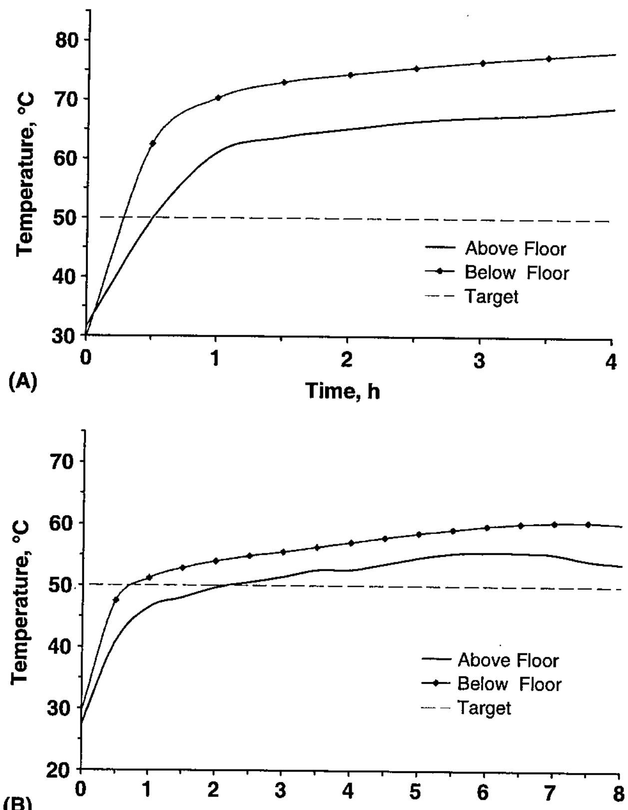


Fig. 2. Propane system 1 (A, 29 kW) and 2 (B, 19 kW), respectively; mean-temperature profile above and below the drying floor of a steel grain bin from three independent replications. A horizontal dashed line indicates the 50 °C target temperature.

Under heated locations could possibly occur in grain debris both above and below the flooring. Grain debris above the flooring should be removed prior to the heat treatment; material below the flooring is likely to be of minimal thickness, which would allow heat penetration. Insects would likely penetrate debris, attempting to survive, but it is unlikely decreased mortality would occur in locations that have minimal quantities of debris. Additional research would be required to determine the rate of heat penetration in larger piles and if treatment times would need to be extended to achieve adequate mortality in any such piles.

Decreased mortality in under heated locations was similar to that reported by Dowdy and Fields (2002) when heat treating a flour mill, where the slower rate of temperature increase was suspected as allowing time for insects to produce heat-shock proteins (HSP) that offered protection at higher temperatures (Denlinger et al., 1991). Quickly raising the bin temperature above 50 °C with the 29 kW propane system 1 resulted in 100% mortality and likely prevented insects from establishing HSP. Increasing the bin temperature quickly may also help prevent insects from fleeing the heat; but during a slow temperature increase, insects have more time to migrate to cooler areas attempting to survive.

Table 3
Propane system 2 (19 kW), insect mortality rate (% mean ± SE) of *Sitophilus oryzae* (L.), *Tribolium castaneum* (Herbst), and *Rhyzopertha dominica* (F.)

Insect species	Floor location	Time (h)		
		4	6	8
1. *S. oryzae*	Above	100 ± 0.0 aA	100 ± 0.0 aA	100 ± 0.0 aA
	Below	80.0 ± 10.0 aA	98.7 ± 1.3 aA	93.3 ± 6.6 aA
2. *T. castaneum*	Above	82.0 ± 10.6 aA	99.0 ± 1.0 aA	100 ± 0.0 aA
	Below	46.6 ± 6.6 bB	76.0 ± 0.0 bA	78.6 ± 7.4 bA
3. *R. dominica*	Above	77.6 ± 14.6 aA	94.6 ± 3.9 aA	100 ± 0.0 aA
	Below	52.0 ± 6.1 aB	74.6 ± 3.5 bA	82.6 ± 1.3 bA

Each of three replications had insect arenas positioned at independent locations with six above and five below the steel grain bin drying floor. Each arena contained five insects of each of three species, with insect mortality determined for three time intervals.
For each of the three species, means for above and below the floor location followed by the same lower-case level are not significantly different; means between time intervals followed by the same upper-case letter are not significantly different ($P \geqslant 0.05$, Waller–Duncan k-ratio t-test).

Table 4
Electric heating system insect mortality rate (% mean ± SE) of *Sitophilus oryzae* (L.), *Tribolium castaneum* (Herbst), and *Rhyzopertha dominica* (F.)

Heating system	Insect species	Floor location	Time (h)		
			12	27	40
Electric system 1 (18 kW)	*S. oryzae*	Above	100 ± 0.0 aA	95.3 ± 4.6 aA	100 ± 0.0 aA
		Below	81.3 ± 14.8 aA	100 ± 0.0 aA	100 ± 0.0 aA
	T. castaneum	Above	88.6 ± 11.3 aA	86.6 ± 13.3 aA	100 ± 0.0 aA
		Below	44.0 ± 2.3 bB	50.6 ± 5.8 aB	100 ± 0.0 aA
	R. dominica	Above	87.6 ± 12.3 aA	86.6 ± 13.3 aA	100 ± 0.0 aA
		Below	49.3 ± 1.3 bB	54.6 ± 2.6 aB	100 ± 0.0 aA
Electric system 2 (18 kW)	*S. oryzae*	Above	100 ± 0.0 aA	100 ± 0.0 aA	100 ± 0.0 aA
		Below	98.6 ± 1.3 aA	100 ± 0.0 aA	100 ± 0.0 aA
	T. castaneum	Above	100 ± 0.0 aA	100 ± 0.0 aA	100 ± 0.0 aA
		Below	56.0 ± 14.0 bA	74.6 ± 5.3 bA	81.3 ± 1.3 bA
	R. dominica	Above	100 ± 0.0 aA	100 ± 0.0 aA	100 ± 0.0 aA
		Below	53.3 ± 13.3 bA	73.3 ± 6.6 bA	81.3 ± 1.3 bA
Electric system 3 (15 kW)	*S. oryzae*	Above	100 ± 0.0 aA	100 ± 0.0 aA	100 ± 0.0 aA
		Below	77.3 ± 2.6 bB	100 ± 0.0 aA	100 ± 0.0 aA
	T. castaneum	Above	100 ± 0.0 aA	100 ± 0.0 aA	100 ± 0.0 aA
		Below	49.3 ± 5.8 bB	84.0 ± 8.3 aA	89.3 ± 3.5 bA
	R. dominica	Above	89.6 ± 5.2 aA	100 ± 0.0 aA	100 ± 0.0 aA
		Below	49.3 ± 5.8 bB	76.0 ± 4.0 bA	85.3 ± 2.6 bA

Each of three replications had insect arenas positioned at independent locations of six above and five below the steel grain bin drying floor. Each arena contained five insects of each of three species, with insect mortality determined for three time intervals. Every control arena had 0% mortality for all insects.
For each of the nine combinations of heating system and insect species, means for above and below the floor location followed by the same lower-case letter are not significantly different; means between time intervals followed by the same upper-case letter are not significantly different ($P \geqslant 0.05$, Waller–Duncan *k*-ratio *t*-test).

Temperature-related mortality is often linked to duration of insect heat exposure (Dowdy, 1999; Dowdy and Fields, 2002; Mahroof et al., 2003b). Arthur (2006) reported that complete mortality of all life stages at temperatures of 51 and 54 °C should occur in a matter of hours; therefore, even the most heat-tolerant insect stages should be killed during a normal heat treatment. The adult life stage was tested in all heat treatment applications. However, complete mortality of all life stages in the grain bin would likely occur in a matter of hours when temperatures exceed 50 °C.

With the propane heater output reduced to 19 kW, temperatures decreased by a maximum of 30 °C below the drying floor when compared to the 29 kW results. The lower bin temperature produced lower mortality rates, particularly below the drying floor. The *T. castaneum* and *R. dominica* had significantly different mortality rates below the floor between 4 and 6 h and both above and below the floor for each time period, except the 4-h period for the *R. dominica*. The efficacy of the treated bin was mainly a function of the heater's power rating and ambient temperature for the tested systems, although use of an interior distribution system or recirculation of exhaust air increased test temperatures for the systems with marginal power output.

Electric system 1 (18 kW) reached the critical 50 °C threshold mean temperature in 2.3 h at all test locations above the drying floor. Below the floor, the mean temperature reached 50 °C in 2 h (Fig. 3A), but locations farthest from the heat source increased much slower. The *T. castaneum* and *R. dominica* had significantly different mortality rates between 12 and 27 h. The differences in mortality rates are likely due to localized overheating and underheating below the floor. After 40 h, electric system 1 resulted in 100% mortality at all test locations. However, the energy requirement for electric system 1 was much greater than for the other heating systems (Table 1), which would increase the total cost of this system.

All of the test-location temperatures were affected by outside temperatures, decreasing slightly as the ambient air-cooled and increasing as the air temperature increased. This effect was particularly noticeable during tests with electric system 3 (Fig. 3C). Electric system 3 tests were conducted on bin 1, located outside; and electric system 2 was conducted with bin 3, located inside. The high mid-day ambient air temperature, combined with solar radiation on the steel bin, raised the temperatures between 16 and 24 h as shown in Fig. 3C. The electric system 3 mortality below the floor increased significantly between 12 and 27 h (Table 4) for each insect species. This indicates that

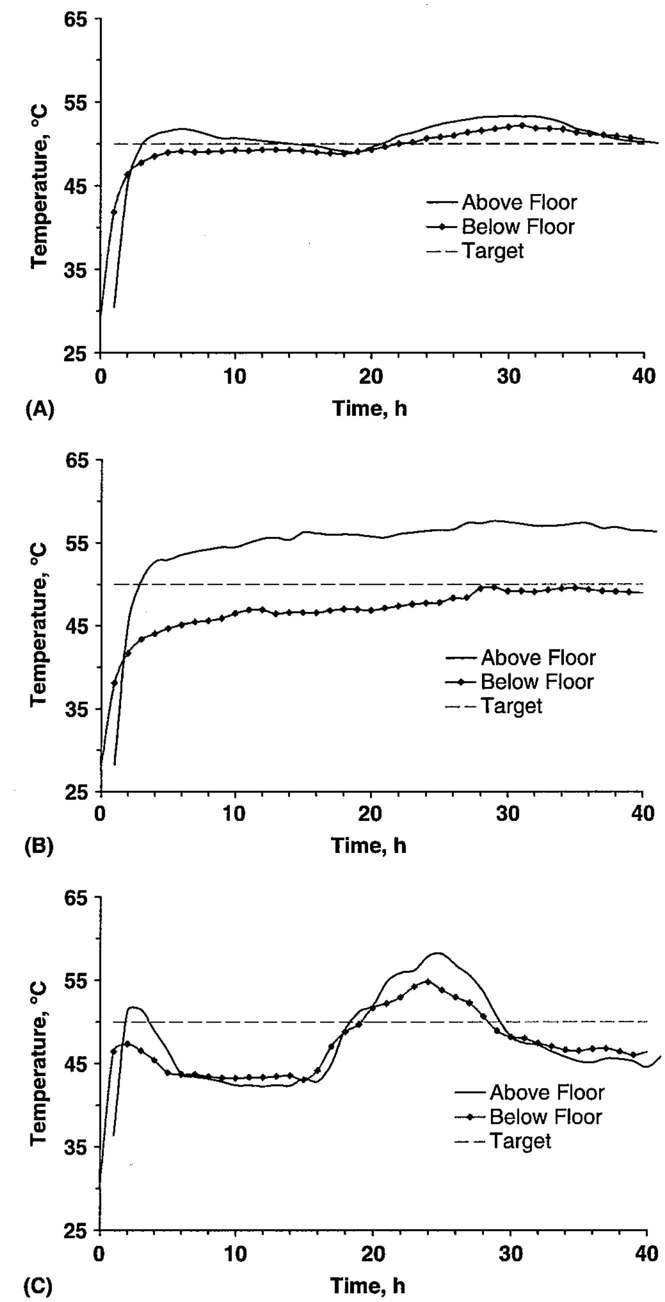


Fig. 3. Mean-temperature profile above and below the grain bin drying floor from three independent replications for electric systems 1, 2, and 3 in A, B, and C, respectively; electric system 1 is an 18 kW duct heater with a distributor; electric system 2 is an 18 kW duct heater with recirculation; electric system 3 is a portable 15 kW heater with recirculation. A horizontal dashed line indicates the 50 °C target temperature.

distribution of air below the flooring approached a minimum of 50 °C or higher, between 12 and 27 h. Although the below-floor mean temperature profile for this system was greater than 50 °C between 2 and 4 h (Fig. 3C), localized overheating and under heating occurred as indicated by low mortality at 12 h. The system had significantly different mortality rates above and below the flooring for the *R. dominica* at 12, 27, and 40 h; for the *T. castaneum* at 12 and 40 h; and for the *S. oryzae* at 12 h. Also, the above- and below-flooring temperatures were significantly different for each time interval (Table 2), likely due to the distribution of air. *S. oryzae* mortality occurred at lower temperatures and much earlier in each test application compared to the *T. castaneum* and *R. dominica*, which showed that this species was much more susceptible to control by heat treatment than the other two.

Electric system 2 resulted in 100% mortality above the flooring for each insect species. Below-floor mortality was excellent for the *S. oryzae* and was significantly different at each time interval for the *T. castaneum* and *R. dominica* (Table 4). However, electric system 1 had 100% mortality after 40 h of operation. The high efficacy of this system was likely due to the interior distribution system that helped reduce the cool spots, combined with high ambient air temperatures. The interior distribution system pulled hot air across the bin below the drying floor, providing more heat to locations farthest from the heat source. When the interior distribution system was replaced by recirculation (electric system 2), mean temperatures were higher while mortalities were lower. All three electric systems had borderline power available to heat treat the steel grain bin. Electric system 2 produced temperatures above the drying floor greater than 50 °C for 37 h and a minimum of 6.6 h during electric system 3 tests. But as the ambient temperature began to decrease late in the day with electric system 3, test temperatures decreased and fell below 50 °C for all locations above the drying floor (Fig. 3C).

Disinfestation of empty steel grain bins prior to storage was successful with some of these readily available systems tested for heat treatment. However, if heat treatments are to receive widespread usage, development of heat tolerance should be closely monitored. Thermotolerance, or the ability to withstand elevated temperatures in organisms, including insects, is attained by genetic adaptation, long-term thermal acclimation, and rapid heat hardening (Hallman and Denlinger, 1998). One of the physiological changes an organism undergoes during the process of developing thermotolerance is the expression of HSP (Currie and Tufts, 1997). These proteins can be monitored to detect development of increased thermotolerance in insect populations that experience continued heat treatments (Mahroof et al., 2006).

4. Conclusions

The best-performing heat-treatment systems tested provided an effective method for pre-binning sanitation as part of an integrated pest management program. Specific conclusions based on the results of these tests were as follows:

- The 29 kW propane system was the most effective, producing 100% mortality for all three insect species in 2 h.
- The 18 kW electric system with duct heater and interior fan/manifold distribution was effective after 40 h of

operation, but required a complicated setup to achieve adequate heat distribution.

- Ambient temperatures and heater power rating were the biggest factors in determining the success of a heat treatment; however, coordinating with times of high ambient temperature enhanced the efficacy of heat treatments.
- Effective heat treatments were obtained when heater power rating was adequate. Effective heat treatments were also possible in some cases with marginal heater power ratings, but these systems required extra effort to recirculate exhaust air or distribute the heat to maximize the limited available power.

Acknowledgments

We thank Mr. Brad Racen, Carlton Company, for technical assistance and providing the Chromolox portable electric heater and Mr. Robert Rousser for the fabricating equipment. Authors are grateful to Dr. R. Vance Morey (Biological Systems and Agricultural Engineering Department, University of Minnesota, St. Paul) and Dr. Rizana Mahroof (Department of Entomology, Kansas State University, Manhattan) for reviewing the manuscript.

References

Arthur, F.H., 2006. Initial and delayed mortality of late-instar larvae, pupae, and adults of *Tribolium castaneum* and *Tribolium confusum* (Coleoptera: Tenebrionidae) exposed at variable temperatures and time intervals. Journal of Stored Products Research 42, 1–7.

Campbell, J.F., Arthur, F.H., Mullen, M.A., 2004. Insect management in food processing facilities. Advances in Food and Nutrition 48, 239–295.

Currie, S., Tufts, B., 1997. Synthesis of stress protein 70 (Hsp 70) in rainbow trout (*Oncorhyncus mykis*) red blood cells. Journal of Experimental Biology 200, 607–614.

Dean, G.A., 1911. Heat as a means of controlling mill insects. Journal of Economic Entomology 4, 142–161.

Denlinger, D.L., Joplin, K.H., Chen, C.P., Lee, R.E., 1991. Cold shock and heat shock. In: Lee, R.E., Denlinger, D.L. (Eds.), Insects at Low Temperature. Chapman & Hall, New York, pp. 131–148.

Dowdy, A.K., 1999. Mortality of red flour beetle, *Tribolium castaneum* (Coleoptera: Tenebrionidae) exposed to high temperature and diatomaceous earth combinations. Journal of Stored Products Research 35, 178–182.

Dowdy, A.K., Fields, P.G., 2002. Heat combined with diatomaceous earth to control the confused flour beetle (Coleoptera: Tenebrionidae) in a flour mill. Journal of Stored Products Research 38, 11–22.

Fields, P.G., 1992. The control of stored-product insects and mites with extreme temperatures. Journal of Stored Products Research 28, 89–118.

Hagstrum, D.W., Reed, C., Kenkel, P., 1999. Management of stored-wheat insect pests in the USA. Integrated Pest Management Reviews 4, 1–17.

Hallman, G.J., Denlinger, D.L., 1998. Introduction: temperature sensitivity and integrated pest management. In: Hallman, G.J., Denlinger, D.L. (Eds.), Temperature Sensitivity in Insects and Application in Integrated Pest Management. Westview Press, Boulder, CO, pp. 1–5.

Imholte, T.J., Imholte-Tauscher, T., 1999. Engineering for food safety and sanitation. Technical Institute of Food Safety, Washington, DC, pp. 303–310.

Mahroof, R., Subramanyam, B., Eustace, D., 2003a. Temperature and relative humidity profiles during heat treatment of mills and its efficacy against *Tribolium castaneum* (Herbst) life stages. Journal of Stored Products Research 39, 555–569.

Mahroof, R., Subramanyam, B., Throne, J., Menon, A., 2003b. Time-mortality relationships for *Tribolium castaneum* (Coleoptera: Tenebrionidae) life stages exposed to elevated temperatures. Journal of Economic Entomology 96, 1345–1351.

Mahroof, R., Zhu, K.Y., Subramanyam, B., 2006. Changes in expression of heat-shock proteins in *Tribolium castaneum* (Coleoptera: Tenebrionidae) in relation to developmental stage, exposure time, and temperature. Annals of the Entomological Society of America 98, 100–107.

Raney, H.G., 1974. Management of on-farm stored grain. University of Kentucky, Cooperative Extension Service, pp. 59–79.

Roesli, R., Subramanyam, B., Fairchild, F.J., Behnke, K.C., 2003. Trap catches of stored-product insects before and after heat treatment in a pilot feed mill. Journal of Stored Products Research 39, 521–540.

SAS Institute, 2002. The SAS System for Windows, release 8.0 SAS Insititute, Cary, NC, USA.

Subramanyam, B., Hagstrum, D.W., 1995. Sampling. In: Subramanyam, B., Hagstrum, D.W. (Eds.), Integrated Management of Insects in Stored Products. Marcel Dekker Inc., New York, pp. 135–193.

Wright, E.J., Sinclair, E.A., Annis, P.C., 2002. Laboratory determination of the requirements for control of *Trogoderma variabile* (Coleoptera: Dermestidae). Journal of Stored Products Research 38, 147–155.

IPPC

INTERNATIONAL STANDARDS FOR PHYTOSANITARY MEASURES

Revision of ISPM No. 15

REGULATION OF WOOD PACKAGING MATERIAL IN INTERNATIONAL TRADE

(2009)

FAO FIAT PANIS

CONTENTS

INTRODUCTION

SCOPE

This standard describes phytosanitary measures that reduce the risk of introduction and spread of quarantine pests associated with the movement in international trade of wood packaging material made from raw wood. Wood packaging material covered by this standard includes dunnage but excludes wood packaging made from wood processed in such a way that it is free from pests (e.g. plywood).

The phytosanitary measures described in this standard are not intended to provide ongoing protection from contaminating pests or other organisms.

ENVIRONMENTAL STATEMENT

Pests associated with wood packaging material are known to have negative impacts on forest health and biodiversity. Implementation of this standard is considered to reduce significantly the spread of pests and subsequently their negative impacts. In the absence of alternative treatments being available for certain situations or to all countries, or the availability of other appropriate packaging materials, methyl bromide treatment is included in this standard. Methyl bromide is known to deplete the ozone layer. A CPM Recommendation on the *Replacement or reduction of the use of methyl bromide as a phytosanitary measure* (2008) has been adopted in relation to this issue. Alternative treatments that are more environmentally friendly are being pursued.

REFERENCES

Consignments in transit, 2006. ISPM No. 25, FAO, Rome.
Export certification system, 1997. ISPM No. 7, FAO, Rome.
Glossary of phytosanitary terms, 2008. ISPM No. 5, FAO, Rome.
Guidelines for a phytosanitary import regulatory system, 2004. ISPM No. 20, FAO, Rome.
Guidelines for inspection, 2005. ISPM No. 23, FAO, Rome.
Guidelines on notification of non-compliance and emergency action, 2001. ISPM No. 13, FAO, Rome.
ISO 3166-1-alpha-2 code elements (http://www.iso.org/iso/english_country_names_and_code_elements).
International Plant Protection Convention, 1997. FAO, Rome.
Phytosanitary treatments for regulated pests, 2007. ISPM No. 28, FAO, Rome.
Replacement or reduction of the use of methyl bromide as a phytosanitary measure, 2008. CPM Recommendation, FAO, Rome.
The Montreal Protocol on Substances that Deplete the Ozone Layer, 2000. Ozone Secretariat, United Nations Environment Programme. ISBN: 92-807-1888-6 (http://www.unep.org/ozone/pdfs/Montreal-Protocol2000.pdf).

DEFINITIONS

Definitions of phytosanitary terms used in this standard can be found in ISPM No. 5 (*Glossary of phytosanitary terms*, 2008).

OUTLINE OF REQUIREMENTS

Approved phytosanitary measures that significantly reduce the risk of pest introduction and spread via wood packaging material consist of the use of debarked wood (with a specified tolerance for remaining bark) and the application of approved treatments (as prescribed in Annex 1). The application of the recognized mark (as prescribed in Annex 2) ensures that wood packaging material subjected to the approved treatments is readily identifiable. The approved treatments, the mark and its use are described.

The National Plant Protection Organizations (NPPOs) of exporting and importing countries have specific responsibilities. Treatment and application of the mark must always be under the authority of the NPPO. NPPOs that authorize the use of the mark should supervise (or, as a minimum, audit or review) the application of the treatments, use of the mark and its application, as appropriate, by producer/treatment providers and should establish inspection or monitoring and auditing procedures. Specific requirements apply to wood packaging material that is repaired or remanufactured. NPPOs of importing countries should accept the approved phytosanitary measures as the basis for authorizing entry of wood packaging material without further wood packaging material-related phytosanitary import requirements and may verify on import that the requirements of the standard have been met. Where wood packaging material does not

comply with the requirements of this standard, NPPOs are also responsible for measures implemented and notification of non-compliance, as appropriate.

REQUIREMENTS

1. Basis for Regulation

Wood originating from living or dead trees may be infested by pests. Wood packaging material is frequently made of raw wood that may not have undergone sufficient processing or treatment to remove or kill pests and therefore remains a pathway for the introduction and spread of quarantine pests. Dunnage in particular has been shown to present a high risk of introduction and spread of quarantine pests. Furthermore, wood packaging material is very often reused, repaired or remanufactured (as described in section 4.3). The true origin of any piece of wood packaging material is difficult to determine, and thus its phytosanitary status cannot easily be ascertained. Therefore the normal process of undertaking pest risk analysis to determine if measures are necessary, and the strength of such measures, is frequently not possible for wood packaging material. For this reason, this standard describes internationally accepted measures that may be applied to wood packaging material by all countries to reduce significantly the risk of introduction and spread of most quarantine pests that may be associated with that material.

2. Regulated Wood Packaging Material

These guidelines cover all forms of wood packaging material that may serve as a pathway for pests posing a pest risk mainly to living trees. They cover wood packaging material such as crates, boxes, packing cases, dunnage[1], pallets, cable drums and spools/reels, which can be present in almost any imported consignment, including consignments that would not normally be subject to phytosanitary inspection.

2.1 Exemptions

The following articles are of sufficiently low risk to be exempted from the provisions of this standard[2]:

- wood packaging material made entirely from thin wood (6 mm or less in thickness)
- wood packaging made wholly of processed wood material, such as plywood, particle board, oriented strand board or veneer that has been created using glue, heat or pressure, or a combination thereof
- barrels for wine and spirit that have been heated during manufacture
- gift boxes for wine, cigars and other commodities made from wood that has been processed and/or manufactured in a way that renders it free of pests
- sawdust, wood shavings and wood wool
- wood components permanently attached to freight vehicles and containers.

3. Phytosanitary Measures for Wood Packaging Material

This standard describes phytosanitary measures (including treatments) that have been approved for wood packaging material and provides for the approval of new or revised treatments.

3.1 Approved phytosanitary measures

The approved phytosanitary measures described in this standard consist of phytosanitary procedures including treatments and marking of the wood packaging material. The application of the mark renders the use of a phytosanitary certificate unnecessary as it indicates that the internationally accepted phytosanitary measures have been applied. These phytosanitary measures should be accepted by all National Plant Protection Organizations (NPPOs) as the basis for authorizing the entry of wood packaging material without further specific requirements. Required phytosanitary measures beyond an approved measure as described in this standard require technical justification.

---

[1] Consignments of wood (i.e. timber/lumber) may be supported by dunnage that is constructed from wood of the same type and quality and that meets the same phytosanitary requirements as the wood in the consignment. In such cases, the dunnage may be considered as part of the consignment and may not be considered as wood packaging material in the context of this standard.

[2] Not all types of gift boxes or barrels are constructed in a manner that renders them pest free, and therefore certain types may be considered to be within the scope of this standard. Where appropriate, specific arrangements related to these types of commodities may be established between importing and exporting NPPOs.

The treatments described in Annex 1 are considered to be significantly effective against most pests of living trees associated with wood packaging material used in international trade. These treatments are combined with the use of debarked wood for construction of wood packaging, which also acts to reduce the likelihood of reinfestation by pests of living trees. These measures have been adopted based on consideration of:

- the range of pests that may be affected
- the efficacy of the treatment
- the technical and/or commercial feasibility.

There are three main activities involved in the production of approved wood packaging material (including dunnage): treating, manufacturing and marking. These activities can be done by separate entities, or one entity can do several or all of these activities. For ease of reference, this standard refers to producers (those that manufacture the wood packaging material and may apply the mark to appropriately treated wood packaging material) and treatment providers (those that apply the approved treatments and may apply the mark to appropriately treated wood packaging material).

Wood packaging material subjected to the approved measures shall be identified by application of an official mark in accordance with Annex 2. This mark consists of a dedicated symbol used in conjunction with codes identifying the specific country, the responsible producer or treatment provider, and the treatment applied. Hereafter, all components of such a mark are referred to collectively as "the mark". The internationally recognized, non-language-specific mark facilitates identification of treated wood packaging material during inspection prior to export, at the point of entry, or elsewhere. NPPOs should accept the mark as referred to in Annex 2 as the basis for authorizing the entry of wood packaging material without further specific requirements.

Debarked wood must be used for the construction of wood packaging material, in addition to application of one of the adopted treatments specified in Annex 1. A tolerance for remaining bark is specified in Annex 1.

3.2 Approval of new or revised treatments

As new technical information becomes available, existing treatments may be reviewed and modified, and new alternative treatments and/or treatment schedule(s) for wood packaging material may be adopted by the Commission on Phytosanitary Measures (CPM). ISPM No. 28 (*Phytosanitary treatments for regulated pests*, 2007) provides guidance on the IPPC's process for approval of treatments. If a new treatment or a revised treatment schedule is adopted for wood packaging material and incorporated into this ISPM, material already treated under the previous treatment and/or schedule does not need to be re-treated or re-marked.

3.3 Alternative bilateral arrangements

NPPOs may accept measures other than those listed in Annex 1 by bilateral arrangement with their trading partners. In such cases, the mark shown in Annex 2 must not be used unless all requirements of this standard have been met.

4. Responsibilities of NPPOs

To meet the objective of preventing the introduction and spread of pests, exporting and importing contracting parties and their NPPOs have responsibilities (as outlined in Articles I, IV and VII of the IPPC). In relation to this standard, specific responsibilities are outlined below.

4.1 Regulatory considerations

Treatment and application of the mark (and/or related systems) must always be under the authority of the NPPO. NPPOs that authorize use of the mark have the responsibility for ensuring that all systems authorized and approved for implementation of this standard meet all necessary requirements described within the standard, and that wood packaging material (or wood that is to be made into wood packaging material) bearing the mark has been treated and/or manufactured in accordance with this standard. Responsibilities include:

- authorization, registration and accreditation, as appropriate
- monitoring treatment and marking systems implemented in order to verify compliance (further information on related responsibilities is provided in ISPM No. 7: *Export certification system*, 1997)
- inspection, establishing verification procedures and auditing where appropriate (further information

is provided in ISPM No. 23: *Guidelines for inspection*, 2005).

The NPPO should supervise (or, as a minimum, audit or review) the application of the treatments, and authorize use of the mark and its application as appropriate. To prevent untreated or insufficiently/incorrectly treated wood packaging material bearing the mark, treatment should be carried out prior to application of the mark.

4.2 Application and use of the mark

The specified marks applied to wood packaging material treated in accordance with this standard must conform to the requirements described in Annex 2.

4.3 Treatment and marking requirements for wood packaging material that is reused, repaired or remanufactured

NPPOs of countries where wood packaging material that bears the mark described in Annex 2 is repaired or remanufactured have responsibility for ensuring and verifying that systems related to export of such wood packaging material comply fully with this standard.

4.3.1 Reuse of wood packaging material

A unit of wood packaging material that has been treated and marked in accordance with this standard and that has not been repaired, remanufactured or otherwise altered does not require re-treatment or re-application of the mark throughout the service life of the unit.

4.3.2 Repaired wood packaging material

Repaired wood packaging material is wood packaging material that has had up to approximately one third of its components removed and replaced. NPPOs must ensure that when marked wood packaging material is repaired, only wood treated in accordance with this standard is used for the repair, or wood constructed or fabricated from processed wood material (as described in section 2.1). Where treated wood is used for the repair, each added component must be individually marked in accordance with this standard.

Wood packaging material bearing multiple marks may create problems in determining the origin of the wood packaging material if pests are found associated with it. It is recommended that NPPOs of countries where wood packaging material is repaired limit the number of different marks that may appear on a single unit of wood packaging material. Therefore NPPOs of countries where wood packaging material is repaired may require the repaired wood packaging material to have previous marks obliterated, the unit to be re-treated in accordance with Annex 1, and the mark then applied in accordance with Annex 2. If methyl bromide is used for the re-treatment, the information in the CPM Recommendation on the *Replacement or reduction of the use of methyl bromide as a phytosanitary measure* (2008) should be taken into account.

In circumstances where there is any doubt that all components of a unit of repaired wood packaging material have been treated in accordance with this standard, or the origin of the unit of wood packaging material or its components is difficult to ascertain, the NPPOs of countries where wood packaging material is repaired should require the repaired wood packaging material to be re-treated, destroyed, or otherwise prevented from moving in international trade as wood packaging material compliant with this standard. In the case of re-treatment, any previous applications of the mark must be permanently obliterated (e.g. by covering with paint or grinding). After re-treatment, the mark must be applied anew in accordance with this standard.

4.3.3 Remanufactured wood packaging material

If a unit of wood packaging material has had more than approximately one third of its components replaced, the unit is considered to be remanufactured. In this process, various components (with additional reworking if necessary) may be combined and then reassembled into further wood packaging material. Remanufactured wood packaging material may therefore incorporate both new and previously used components.

Remanufactured wood packaging material must have any previous applications of the mark permanently obliterated (e.g. by covering with paint or grinding). Remanufactured wood packaging material must be re-treated and the mark must then be applied anew in accordance with this standard.

4.4 Transit

Where consignments moving in transit have wood packaging material that does not meet the requirements of this standard, NPPOs of countries of transit may require measures to ensure that wood packaging material does not present an unacceptable risk. Further guidance on transit arrangements is provided in ISPM No. 25 (*Consignments in transit*, 2006).

4.5 Procedures upon import

Since wood packaging materials are associated with most shipments, including those not considered to be the target of phytosanitary inspections in their own right, cooperation by NPPOs with organizations not usually involved with verification of whether the phytosanitary import requirements have been met is important. For example, cooperation with Customs organizations and other stakeholders will help NPPOs in receiving information on the presence of wood packaging material. This is important to ensure effectiveness in detecting potential non-compliance of wood packaging material.

4.6 Phytosanitary measures for non-compliance at point of entry

Relevant information on non-compliance and emergency action is provided in sections 5.1.6.1 to 5.1.6.3 of ISPM No. 20 (*Guidelines for a phytosanitary import regulatory system*, 2004), and in ISPM No. 13 (*Guidelines on notification of non-compliance and emergency action*, 2001). Taking into account the frequent re-use of wood packaging material, NPPOs should consider that the non-compliance identified may have arisen in the country of production, repair or remanufacture, rather than in the country of export or transit.

Where wood packaging material does not carry the required mark, or the detection of pests provides evidence that the treatment may not have been effective, the NPPO should respond accordingly and, if necessary, an emergency action may be taken. This action may take the form of detention while the situation is being addressed then, as appropriate, removal of non-compliant material, treatment[3], destruction (or other secure disposal) or reshipment. Further examples of appropriate options for actions are provided in Appendix 1. The principle of minimal impact should be pursued in relation to any emergency action taken, distinguishing between the consignment traded and the accompanying wood packaging material. In addition, if emergency action is necessary and methyl bromide is used by the NPPO, relevant aspects of the CPM Recommendation on *Replacement or reduction of the use of methyl bromide as a phytosanitary measure* (2008) should be followed.

The NPPO of the importing country should notify the exporting country, or the manufacturing country where applicable, in cases where live pests are found. In such cases, where a unit of wood packaging material bears more than one mark NPPOs should attempt to determine the origin of the non-compliant component(s) prior to sending a notice of non-compliance. NPPOs are also encouraged to notify cases of missing marks and other cases of non-compliance. Taking into account the provisions of section 4.3.2, it should be noted that the presence of multiple marks on a single unit of wood packaging does not constitute non-compliance.

[3] This need not necessarily be a treatment approved in this standard.

ANNEX 1

APPROVED TREATMENTS ASSOCIATED WITH WOOD PACKAGING MATERIAL

Use of debarked wood

Irrespective of the type of treatment applied, wood packaging material must be made of debarked wood. For this standard, any number of visually separate and clearly distinct small pieces of bark may remain if they are:

- less than 3 cm in width (regardless of the length) or
- greater than 3 cm in width, with the total surface area of an individual piece of bark less than 50 square cm.

For methyl bromide treatment the removal of bark must be carried out before treatment because the presence of bark on the wood affects the efficacy of the methyl bromide treatment. For heat treatment, the removal of bark can be carried out before or after treatment.

Heat treatment (treatment code for the mark: HT)

Wood packaging material must be heated in accordance with a specific time–temperature schedule that achieves a minimum temperature of 56 °C for a minimum duration of 30 continuous minutes throughout the entire profile of the wood (including at its core). Various energy sources or processes may be suitable to achieve these parameters. For example, kiln-drying, heat-enabled chemical pressure impregnation, microwave or other treatments may all be considered heat treatments provided that they meet the heat treatment parameters specified in this standard.

Methyl bromide treatment (treatment code for the mark: MB)

Use of methyl bromide should be undertaken taking into account the CPM Recommendation *Replacement or reduction of the use of methyl bromide as a phytosanitary measure* (2008). NPPOs are encouraged to promote the use of alternative treatments approved in this standard.[4]

The wood packaging material must be fumigated with methyl bromide in accordance with a schedule that achieves the minimum concentration-time product[5] (CT) over 24 hours at the temperature and final residual concentration specified in Table 1. This CT must be achieved throughout the wood, including at its core, although the concentrations would be measured in the ambient atmosphere. The minimum temperature of the wood and its surrounding atmosphere must be not less than 10 °C and the minimum exposure time must be not less than 24 hours. Monitoring of gas concentrations must be carried out at a minimum at 2, 4 and 24 hours (in the case of longer exposure times and weaker concentrations, additional measurement should be recorded at the end of fumigation).

Table 1: Minimum CT over 24 hours for wood packaging material fumigated with methyl bromide

Temperature	CT ($g \cdot h/m^3$) over 24 h	Minimum final concentration (g/m^3) after 24 h
21 °C or above	650	24
16 °C or above	800	28
10 °C or above	900	32

One example of a schedule that may be used for achieving the specified requirements is shown in Table 2.

[4] In addition, contracting parties to the IPPC may also have obligations under the Montreal Protocol on Substances that deplete the Ozone Layer.

[5] The CT product utilized for methyl bromide treatment in this standard is the sum of the product of the concentration (g/m^3) and time (h) over the duration of the treatment.

Table 2: Example of a treatment schedule that achieves the minimum required CT for wood packaging material treated with methyl bromide (initial doses may need to be higher in conditions of high sorption or leakage)

Temperature	Dosage (g/m^3)	Minimum concentration (g/m^3) at:		
		2 h	4 h	24 h
21 °C or above	48	36	31	24
16 °C or above	56	42	36	28
10 °C or above	64	48	42	32

NPPOs shall ensure that the following factors are appropriately addressed by those involved in the application of methyl bromide treatment under this standard:

1. Fans are used as appropriate during the gas distribution phase of fumigation to ensure that equilibrium is reached and should be positioned to ensure that the fumigant is rapidly and effectively distributed throughout the fumigation enclosure (preferably within one hour of application).
2. Fumigation enclosures are not loaded beyond 80% of their volume.
3. Fumigation enclosures are well sealed and as gas tight as possible. If fumigation is to be carried out under sheets, these must be made of gas-proof material and sealed appropriately at seams and at floor level.
4. The fumigation site floor is either impermeable to the fumigant or gas-proof sheets must be laid on the floor.
5. Methyl bromide is often applied through a vaporizer ('hot gassing') in order to fully volatilize the fumigant prior to its entry into the fumigation enclosure.
6. Methyl bromide treatment is not carried out on wood packaging material exceeding 20 cm in cross section. Wood stacks need separators at least every 20 cm to ensure adequate methyl bromide circulation and penetration.
7. When calculating methyl bromide dosage, compensation is made for any gas mixtures (e.g. 2% chloropicrin) to ensure that the total amount of methyl bromide applied meets required dosage rates.
8. Initial dose rates and post-treatment product handling procedures take account of likely methyl bromide sorption by the treated wood packaging material or associated product (e.g. polystyrene boxes).
9. The measured temperature of the product or the ambient air (whichever is the lower) is used to calculate the methyl bromide dose, and must be at least 10 °C (including at the wood core) throughout the duration of the treatment.
10. Wood packaging material to be fumigated is not wrapped or coated in materials impervious to the fumigant.
11. Records of methyl bromide treatments are retained by treatment providers, for a period of length determined and as required by the NPPO, for auditing purposes.

NPPOs should recommend that measures be taken to reduce or eliminate emissions of methyl bromide to the atmosphere where technically and economically feasible (as described in the CPM Recommendation on *Replacement or reduction of the use of methyl bromide as a phytosanitary measure* (2008)).

Adoption of alternative treatments and revisions of approved treatment schedules

As new technical information becomes available, existing treatments may be reviewed and modified, and alternative treatments and/or new treatment schedule(s) for wood packaging material may be adopted by the Commission on Phytosanitary Measures. If a new treatment or a revised treatment schedule is adopted for wood packaging material and incorporated into this ISPM, material treated under the previous treatment and/or schedule does not need to be re-treated or re-marked.

ANNEX 2

THE MARK AND ITS APPLICATION[6]

A mark indicating that wood packaging material has been subjected to approved phytosanitary treatment in accordance with this standard comprises the following required components:
- the symbol
- a country code
- a producer/treatment provider code
- a treatment code using the appropriate abbreviation according to Annex 1 (HT or MB).

Symbol
The design of the symbol (which may have been registered under national, regional or international procedures, as either a trademark or a certification/collective/guarantee mark) must resemble closely that shown in the examples illustrated below and must be presented to the left of the other components.

Country code
The country code must be the International Organization for Standards (ISO) two-letter country code (shown in the examples as "XX"). It must be separated by a hyphen from the producer/treatment provider code.

Producer/treatment provider code
The producer/treatment provider code is a unique code assigned by the NPPO to the producer of the wood packaging material or treatment provider who applies the marks or the entity otherwise responsible to the NPPO for ensuring that appropriately treated wood is used and properly marked (shown in the examples as "000"). The number and order of digits and/or letters are assigned by the NPPO.

Treatment code
The treatment code is an IPPC abbreviation as provided in Annex 1 for the approved measure used and shown in the examples as "YY". The treatment code must appear after the combined country and producer/treatment provider codes. It must appear on a separate line from the country code and producer/treatment provider code, or be separated by a hyphen if presented on the same line as the other codes.

Treatment code	**Treatment type**
HT	Heat treatment
MB	Methyl bromide

Application of the mark
The size, font types used, and position of the mark may vary, but its size must be sufficient to be both visible and legible to inspectors without the use of a visual aid. The mark must be rectangular or square in shape and contained within a border line with a vertical line separating the symbol from the code components. To facilitate the use of stencilling, small gaps in the border, the vertical line, and elsewhere among the components of the mark, may be present.

No other information shall be contained within the border of the mark. If additional marks (e.g. trademarks of the producer, logo of the authorizing body) are considered useful to protect the use of the mark on a national level, such information may be provided adjacent to but outside of the border of the mark.

[6] At import, countries should accept previously produced wood packaging material carrying a mark consistent with earlier versions of this standard.

The mark must be:
- legible
- durable and not transferable
- placed in a location that is visible when the wood packaging is in use, preferably on at least two opposite sides of the wood packaging unit.

The mark must not be hand drawn.

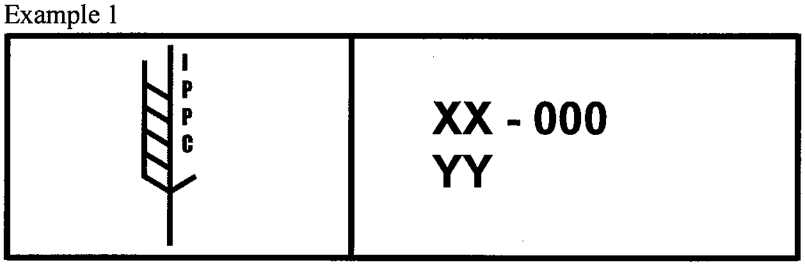
The use of red or orange should be avoided because these colours are used in the labelling of dangerous goods.

Where various components are integrated into a unit of wood packaging material, the resultant composite unit should be considered as a single unit for marking purposes. On a composite unit of wood packaging material made of both treated wood and processed wood material (where the processed component does not require treatment), it may be appropriate for the mark to appear on the processed wood material components to ensure that the mark is in a visible location and is of a sufficient size. This approach to the application of the mark applies only to composite single units, not to temporary assemblies of wood packaging material.

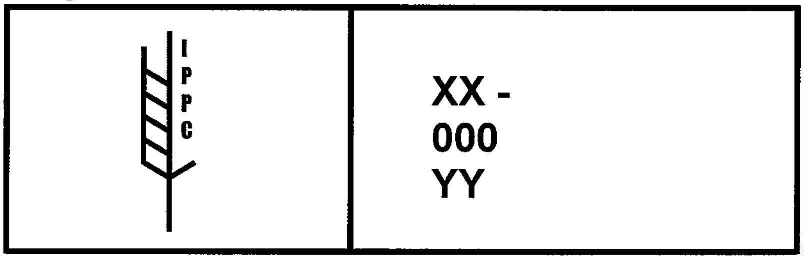
Special consideration of legible application of the mark to dunnage may be necessary because treated wood for use as dunnage may not be cut to final length until loading of a conveyance takes place. It is important that shippers ensure that all dunnage used to secure or support commodities is treated and displays the mark described in this annex, and that the marks are clear and legible. Small pieces of wood that do not include all the required elements of the mark should not be used for dunnage. Options for marking dunnage appropriately include:
- application of the mark to pieces of wood intended for use as dunnage along their entire length at very short intervals (NB: where very small pieces are subsequently cut for use as dunnage, the cuts should be made so that an entire mark is present on the dunnage used.)
- additional application of the mark to treated dunnage in a visible location after cutting, provided that the shipper is authorized in accordance with Section 4.

The examples below illustrate some acceptable variants of the required components of the mark that is used to certify that the wood packaging material that bears such a mark has been subjected to an approved treatment. No variations in the symbol should be accepted. Variations in the layout of the mark should be accepted provided that they meet the requirements set out in this annex.

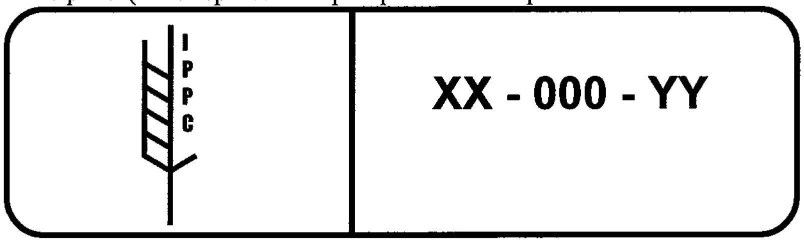
Example 1



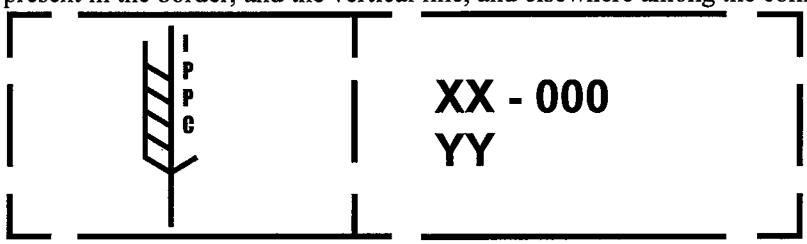
Example 2



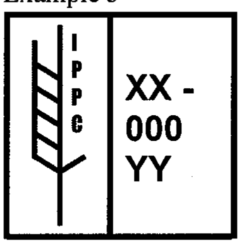
Example 3 (This represents a prospective example of a mark with the border with rounded corners.)



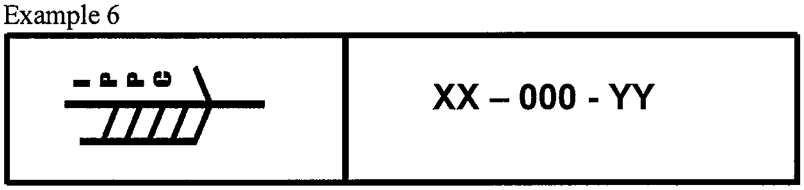
Example 4 (This represents a prospective example of a mark applied by stencilling; small gaps may be present in the border, and the vertical line, and elsewhere among the components of the mark.)



Example 5



Example 6



APPENDIX 1

This appendix is for reference purposes only and is not a prescriptive part of the standard.

EXAMPLES OF METHODS OF SECURE DISPOSAL OF NON-COMPLIANT WOOD PACKAGING MATERIAL

Secure disposal of non-compliant wood packaging material is a risk management option that may be used by the NPPO of the importing country when an emergency action is either not available or is not desirable. The methods listed below are recommended for the secure disposal of non-compliant wood packaging material:

1. incineration, if permitted
2. deep burial in sites approved by appropriate authorities (NB: the depth of burial may depend on climatic conditions and the pest intercepted, but is recommended to be at least 2 metres. The material should be covered immediately after burial and should remain buried. Note, also, that deep burial is not a suitable disposal option for wood infested with termites or some root pathogens.)
3. processing (NB: Chipping should be used only if combined with further processing in a manner approved by the NPPO of the importing country for the elimination of pests of concern, e.g. the manufacture of oriented strand board.)
4. other methods endorsed by the NPPO as effective for the pests of concern
5. return to exporting country, if appropriate.

In order to minimize the risk of introduction or spread of pests, secure disposal methods where required should be carried out with the least possible delay.